

## ELECTRICAL DEVICE AND OPERATING METHOD

~~Field of the Invention~~ Field of the Invention

The present invention relates to an electrical device according to the definition of the species in Claim 1 and a corresponding an operating method according to the definition of the species in Claim 10. Such an in which the electrical device is provided for the combined voltage and torque control of an electrical machine converting mechanical energy to electrical energy, such as a generator in the electrical system of a motor vehicle.

Background Information

10 It is known that switching into the vehicle's electrical system an electrical consumer having high electrical power results in a high load on the generator. Since switching on the electrical consumer leads to a voltage dip in the vehicle's electrical system, a voltage controller assigned to the generator tries to increase  
15 the power supplied by the generator by increasing the exciting current. However, this results in the braking torque caused by the generator being increased in such a way that, especially in response to a low rotary speed of the internal combustion engine, an interfering sudden drop of the rotary speed may occur. In order  
20 to ~~hold~~ minimize such a sudden drop in the rotary speed ~~to as small as possible~~, measures are provided in systems that have a so-called load-response device which prevents the generator from being loaded too greatly. It is thereby also prevented that a sudden drop in rotary speed occurs in the combustion engine. However, since  
25 the required electrical power can no longer be supplied, an undesired voltage dip can now occur.

Such a rotary speed change can be countered, at least in certain operating states, in that a sufficient excess torque is supplied.

However, this leads to increased usage, in a disadvantageous manner. ~~Furthermore~~As an alternative, the generator adjustment can be specifically slowed down. However, this may lead disadvantageously to an increase in the fluctuations of the voltage of the vehicle's electrical system. Such fluctuations are undesired, however, since they disadvantageously influence the service life of the battery, and are able to damage component parts that are sensitive to voltage. ~~Furthermore~~As an alternative, an additional consumer could be switched on in a specified manner via a ramp function. However, this requires a greater switching technology expenditure, and therefore leads to higher product costs. In all the alternatives mentioned, an optimum adaptation to the actually available excess torque is not readily possible.

A method is ~~known from~~described in published German patent document DE 39 31 897 A1 for voltage control for generators in motor vehicles, in which, in a first time interval, the generator output voltage is set to a maximum value, so that reliable loading of the vehicle's battery takes place independently of the environmental temperature. In a second time interval, the generator output voltage is regulated usually as a function of the battery temperature, according to a known method. In this context, the establishment of the first time interval takes place as a function of the loading state of the battery.

#### ~~Detailed Description of the Present Invention~~Summary

~~The design approach according to the present invention~~  
~~creates~~provides a possibility, during operation of the device, to adapt the adjustment speed of the ~~of the~~ voltage situation to the actual speed of the torque provisioning. For this, a ~~coordinated~~coordinating unit is provided which establishes in which way individual variables are set and changed, in order to obtain optimum control. The control concept according to the present invention makes it possible for this coordinating unit to adjust extreme conditions, such as voltage control at great torque

changes, torque control at strong voltage fluctuations, as well as any intermediate conditions. Lastly, this leads to an adaptation of the dynamics of the generator to the actually possible engine dynamics.

- 5 The variables voltage and torque are examined in parallel. The generator control may be divided into three areas of control, in this context.

10 The first area of control relates to a voltage control in the immediate surround field of the setpoint voltage, and in response to changes in the braking torque, only up to the set excess torque.

15 The second area of control relates to the situation in which the generator cannot adjust the load change and the voltage change using the available excess torque, but the voltage deviation is still just within the admissible boundaries. In this context, the boundary value (excess torque) is able to be changed within the possibilities of the torque buildup in any time-dependent manner. Different strategies may be implemented, in this context, depending on the objective.

20 The third area of control relates to the situation in which the vehicle's electrical system voltage lies outside admissible boundaries. In this case the voltage control has the highest priority. The boundaries of the areas mentioned may even, ~~in this context,~~ be displaced at will, within the meaning of optimum adjustment.

#### 25 ~~Brief Description of the Drawings~~

~~The present invention is explained below in detail on the basis of the drawing. The figures show:~~

#### Brief Description of the Drawings

30 Figure 1 shows a first block diagram of a system including a combustion engine and an electrical device having a generator and a vehicle electrical system.

Figure 2 shows a second block diagram ~~having~~including functional modules for the control of the generator<sub>7</sub>.

Figure 3 shows a third block diagram showing control areas<sub>7</sub>.

Figure 4 shows ~~diverse~~ various curves ~~in one diagram~~ plotted against  
5 time.

#### ~~Variants of the Embodiment~~ Detailed Description

Figure 1 shows a first block diagram of a system 1 including a combustion engine and a device having a generator and a vehicle electrical system. Various functional modules are shown

10 schematically, and so are the functional connections between these functional modules. Reference numeral 10 designates a combustion engine, reference numeral 11 designates an electronic engine control assigned to the combustion engine. Reference numeral 12 designates an electric generator which includes an electrical  
15 machine 12A and a controller 12B. Electrical machine 12A is driven by combustion engine 10, and converts the mechanical energy generated by combustion engine 10 to the electrical energy required for a vehicle electrical system. The vehicle electrical system shown only schematically is designated by Reference numeral 13.  
20 System 1 also includes a functional module battery management, which bears reference numeral 14. Vehicle electrical system 13 and generator 12 are linked via load current  $I_{Last}$ . When a a-strong electrical consumer is switched on in vehicle electrical system 13, such as a rear window heater in the wintertime, a great change  
25 with time  $dI_{Last}/dt$  of load current  $I_{Last}$  takes place, and consequently a high load on generator 12 is triggered. The great change with time of the load current, in this case a great increase of load current  $I_{Last}$ , leads to a sudden drop in voltage  $U_{Gen}$  that is given off by electrical machine 12A. Electrical machine  
30 12A and controller 12B are linked to each other via the variables voltage  $U_{Gen}$  and exciting current  $I_{Err}$ . As soon as controller 12B records the drop in voltage  $U_{Gen}$ , it tries to increase the

power given off by generator 12 by controlling and  
~~corresponding~~correspondingly increasing of exciting current  $I_{Err}$ .  
However, this also increases the braking torque caused by generator  
12. combustion engine 10 and generator 12 are linked to each other  
5 via the variables torque  $M$  and rotary speed  $n$ , as well as their  
changes with time,  $dM/dt$  and  $dn/dt$ . The increase in exciting  
current  $I_{Err}$  triggered by controller 12B and the increase,  
effected thereby, of braking torque  $M$  of generator 12 have an effect  
on the rotary speed  $n$  of combustion engine 10. Especially in the  
10 case of low rotary speeds  $n$  of combustion engine 10, an undesired  
~~break~~braking of the speed under load may occur. The ~~design approach~~  
~~according to the present invention now creates~~provides a  
possibility, during operation of the above-described system 1, to  
adapt the adjustment speed of the voltage to the actual speed of  
15 the torque provisioning.

Figure 2 shows a second block diagram in which diverse functional  
modules are shown for controlling generator 12, ~~and whose~~  
~~collaboration is shown schematically~~. Generator 12 includes  
electrical machine 12A and a controller 12B. Reference numeral 13  
20 designates a functional module representing the vehicle electrical  
system. Functional module 20 represents the drive train of the  
vehicle. Reference numeral 21 designates at least one control unit  
which coordinates the functional sequence in the control of  
generator 12. The arrows and double arrows shown in Figure 2  
25 indicate functional linkages that exist between the individual  
structural components and functional modules.

The ~~erux of the present invention is to create~~provides an  
electrical device, having a generator, in which an extraordinarily  
flexible control of the generator is made possible, in order to  
30 ensure as great a voltage constancy as possible and as great an  
operating safety as possible. To ~~deachieve~~achieve this, according to the  
present invention, various controlling areas are provided which  
make possible an optimum controlling strategy. This is explained

in the light of Figure 3, which shows a third block diagram showing controlling areas.

This illustration, in turn, also clarifies the interaction between the vehicle electrical system (functional module 13 in Figure 2) and the drive train (functional module 20 in Figure 2). Altogether, essentially three types of controlling areas may be characterized, which are further subdivided if necessary. In a first area 30, which lies in the immediate surround field of setpoint voltage  $U_{Soll}$ , a voltage control is provided. In this context, if changes in torque  $M$  occur, these are permitted up to a specifiable boundary value, excess torque  $M_{\text{Überschuss}}$ . ~~Te~~Next to this first controlling area (area 30), there adjoins a controlling area (areas 31, 32) in which generator 12 is not able to adjust occurring load changes and voltage changes using the available, specifiable excess torque  $M_{\text{Überschuss}}$ , the occurring voltage deviation, however, still being within an admissible voltage range. In this context, the admissible voltage range is determined by the specifiable boundary values  $U_H$  and  $U_L$ . Finally, in a third controlling area (areas 33, 34), there is a situation in which the voltage of vehicle electrical system 13 is outside the admissible voltage range, that is, it exceeds upper boundary value  $U_H$  or undershoots lower boundary value  $U_L$ .

The diagram in Figure 4 shows diverse curves in light of which the functioning of electrical device 1 will be explained below. Curves, which are plotted over a time axis ~~that~~, represent certain variables as functions of time. Curve 42 shows load current  $I_{\text{Last}}$  as a function of time  $T$ . Moreover, torque  $M$  is shown as a function of time  $T$  in curve 41. Finally, generator voltage  $U_{\text{Gen}}$  is shown as a function of time  $T$  in curve 40. In addition, in the area of the curve representing the generator voltage, special voltage values are ~~emphasize~~emphasized, namely, a setpoint value  $U_{Soll}$ , a minimum value  $U_L$  and a maximum value  $U_H$ . In this case, setpoint value  $U_{Soll}$  lies between the extreme values  $U_H$  and  $U_L$  named.

We shall first examine the time interval between a point in time T0 and a point in time T1. Curve 42 shows that load current I\_Last has a certain level and fluctuates only within comparatively narrow boundaries, which indicates an essentially constant load of vehicle electrical system 13. Curve 40, which represents generator voltage U\_Gen, shows that generator voltage U\_Gen is essentially constant and that it is regulated to its setpoint value U\_Soll in the examined time interval T0-T1. Curve 41, representing torque M, also shows relatively low fluctuations of torque M, since quite small torque changes are sufficient for compensating for the fluctuations of load current I\_Last. Consequently, interval T0-T1 corresponds to the first area of control already mentioned above, in which a voltage control takes place in the immediate surround field of setpoint voltage U\_Soll, and in which changes of torque M are ~~admitted~~permitted up to a specifiable excess torque.

As curve 42 shows, load current I\_Last rises steeply at time T1, because an electrical consumer has been switched on that has a large power consumption and that loads vehicle electrical system 13. As curve 40 shows, this great load results in a voltage dip. The generator voltage drops below setpoint voltage U\_Soll and approximates lower boundary value U\_L. At this point the second area of control is present, in which generator 12 is no longer able to adjust the load change and voltage change using the specifiable and available excess torque, but the deviation of the generator voltage is still just within the ~~admissible~~permissible boundary values U\_H and U\_L. In order to compensate for the load change and the voltage deviation ~~connected to~~associated with it, an increase in torque M is provided, and the system ~~goes~~switches over from voltage control to torque control. Torque M rises to a higher value until at time T2 a value of torque M is reached which is sufficient for compensating the load change. At this time T2, generator voltage U\_Gen has reached its setpoint value U\_Soll again, and a voltage control is carried out again. In this connection, the

present invention makes possible an extraordinarily flexible adjustment to difficult operating situations, in order, on the one hand, to compensate for load changes as rapidly as possible, and to guarantee as great as possible a voltage constancy as possible in the process. ~~Thereby~~ In this manner, great reliability of the vehicle electrical system and as great as possible a protection of voltage-sensitive components as possible are achieved.

According to different ~~embodiment-variant~~ example embodiments of the present invention, different strategies may be employed for the control of the torque in the area of torque control. For instance, in a ~~first~~ an example ~~embodiment-variant~~ torque M may rise linearly, the increase being implementable using different slopes. According to one further example ~~embodiment-variant~~, a more complex, nonlinear function may be provided for the rise in torque M, in addition, dynamic adjustments to the respective situation being also possible in order to attain an optimum result. For example, torque M may be changed according to a function  $F=F(T, P)$ , where T is the time and P is an operating parameter of the device. In a further example ~~embodiment-variant~~, a functional dependence of the torque on influencing variables may be implemented also by a corresponding characteristics map K, in which a certain value of torque M is assigned to corresponding values of one or more influencing variables.

As the course of load current  $I_{Last}$  shows according to curve 42 in Figure 4, load current  $I_{Last}$  drops off greatly at time T3. For example, a strongly powered electrical consumer may have been switched off from the vehicle electrical system. It may be seen from the course of curve 40 that, as a result, generator voltage  $U_{Gen}$  rises sharply and even exceeds maximum value  $U_H$ . At this point the third area, mentioned briefly above, is now present, in which the generator voltage lies outside the ~~admissible~~ permissible boundaries  $U_H$ ,  $U_L$ . In this situation, the voltage control has the highest priority, since voltage-sensitive components or



assemblies are greatly at risk. Therefore, as shown in curve 41, it is first taken care that torque M is reduced to a correspondingly low value, in order to attain as fast as possible a voltage drop to a noncritical value. This is the case approximately at time T4, at which the voltage reaches the maximum value U<sub>H</sub> again or falls below it. At this time T4, a torque control sets in again, until the torque that is too high has dropped down to a lower level that is sufficient for the lower power demands, and the voltage has attained its setpoint value U<sub>Soll</sub> again. This is the case approximately as of time T5. Beginning at this point in time, the system ~~geess~~switches over to voltage control.

With the aid of the curve illustrations in Figure 4, a situation was explained in which a rise in voltage above the maximum value has taken place. An analogous controlling procedure would proceed in response to the undershooting of the minimum value U<sub>L</sub> of the voltage.

In one example embodiment~~-variant~~ of the present invention, the values U<sub>Soll</sub>, U<sub>H</sub>, U<sub>L</sub>, may be specified in an application-specific manner, as well as the boundaries between the two controlling types torque control and voltage control and the width of the areas in which the respective control type is dominant.

In one ~~particularly-advantageous~~ example embodiment~~-variant~~ of the present invention, however, it is also possible to ~~to~~ dynamically ~~te~~ adjust at least some of the variables named, even during driving operation of a vehicle equipped with the electrical device. Thus, for example, the boundaries (see illustration in Figure 3), at which switchover takes place between voltage control and torque control, may be designed as a function of operating characteristics variables of the device or of the vehicle. Such a dependence is able to be expediently implemented by appropriate characteristics maps. In a corresponding manner, the widths of the areas, in which a voltage control or a torque control is to take place, or the

transition locations between these two areas, may be designed variably. This example embodiment ~~variant~~ is distinguished by particularly great flexibility.

~~List of reference numerals~~

- ~~1—system,~~  
~~10—combustion engine~~  
~~11—engine control~~  
5 ~~12—generator~~  
~~12A—machine~~  
~~12B—controller~~  
~~13—vehicle electrical system~~  
~~14—battery~~  
10 ~~20—drive train~~  
~~21—control unit~~  
~~30—area~~  
~~31—area~~  
~~32—area~~  
15 ~~33—area~~  
~~34—area~~  
~~40—curve of voltage~~  
~~41—curve of torque~~  
~~42—curve of load current~~  
20 ~~43—time axis~~  
~~M—torque~~  
~~M\_Überschuss—excess torque~~  
~~n—rotary speed~~  
~~T—time~~  
25 ~~T0—time~~  
~~T1—time~~  
~~T2—time~~  
~~T3—time~~  
~~T4—time~~  
30 ~~T5—time~~  
~~dM/dt—change in M with time~~  
~~dn/dt—change in n with time~~  
~~U\_Gen—generator voltage~~

~~U\_Soll — setpoint voltage~~

~~U\_H — maximum value of voltage~~

~~U\_L — minimum value of voltage~~

~~I\_Err — exciting current~~

5 ~~I\_Last — load current~~

~~dI\_Last/dt change in I with time~~

Abstract

ABSTRACT

~~The present invention relates to an~~ An electrical device having a generator ~~(12)~~, particularly, e.g., for use in the vehicle electrical system ~~(13)~~ of a motor vehicle, ~~having~~ includes a  
5 controller ~~(12B)~~ for controlling the generator voltage. In the device, an area ~~(30)~~ is provided ~~for the control~~ in which a voltage control is carried out, and other areas ~~(31,32)~~ are provided in which a torque control is carried out. ~~The present invention also relates to a method for operating such a device.~~

10 ~~(Figure 3)~~